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ScienceDirect

Procedia Manufacturing 11 (2017) 164 – 173

Procedia MANUFACTURING

27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27-30 June 2017, Modena, Italy

Teaching Assembly by Demonstration using Advanced Human Robot Interaction and a Knowledge Integration Framework

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Abstract

Conventional industrial robots are heavily dependent on hard automation that requires pre-specified fixtures and time-consuming (re)programming performed by experienced operators. In this work, teaching by human-only demonstration is used for reducing required time and expertise to setup a robotized assembly station. This is achieved by the proposed framework enhancing the robotic system with advanced perception and cognitive abilities, accessed through a user-friendly Human Robot Interaction interface. The approach is evaluated on a small parts' assembly use case deployed onto a collaborative industrial robot testbed. Experiments indicate that the proposed approach allows inexperienced users to efficiently teach robots new assembly tasks.

Peer-review under responsibility of the scientific committee of the 27th International Conference on Flexible Automation and Intelligent Manufacturing

Keywords: Robotic Assembly; Teaching by Demonstration; Sequential Function Charts; Knowledge Integration

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Peer-review under responsibility of the scientific committee of the 27th International Conference on Flexible Automation and Intelligent Manufacturing
doi:10.1016/j.promfg.2017.07.221

1. Introduction

Conventional industrial robots are heavily dependent on hard automation that requires pre-specified fixtures and time-consuming programming and reprogramming performed by experienced software engineers. Assembly applications, in particular, have proven challenging to automate due to e.g., complex materials, precise grasping requirements, part variations, operations requiring high precision (snap fits), operations requiring special motions (twist insertions) and wear and tear of the assembly equipment. While robotic assembly does exist, it has only been applied in a fraction of the potential cases. As a result, nowadays even expensive products produced in fairly large volumes are still assembled manually in low wage countries under harsh conditions. A potential solution to have a smooth transition towards higher level of autonomy is to include human teachers providing feedback through demonstration. Open questions in this domain include how to design solutions to reduce the required experience and skill level of the robot programmer, make industrial robots available to new users, guide users, and facilitate learning from experience.

Robot Learning from Demonstration (LfD) or Robot Programming by Demonstration (PbD) (also known as Imitation Learning) is a paradigm for equipping robots with skills to autonomously achieve tasks, without manually programming a desired behavior. The idea is to derive robot controllers from observing humans with the aim of adapting to novel cases with minimum expertise. A lot of studies have been reported in this area, [1-3]. An important aspect of the problem is how to convey the information, namely the interface to provide demonstrations. One common way is to record human motions directly [4], other two main approaches are kinesthetic teaching (guiding the robot physically) [5] and teleoperation (human operator using the robot's sensors and effectors) [6]. Our work follows the first of the aforementioned research directions, since it is based on observing human actions visually. There are various motion tracking systems based on vision, or wearable motion sensors [7]. Mapping human actions to robots is an open research area [8]. Our work addresses how to extract semantic information from visual observations for industrial assembly tasks and automatically generate a robotic program to execute the demonstrated task. A key element of LfD/PbD is Human Robot Interaction (HRI) and the technologies employed to facilitate such interaction [9]. Recently, there has also been a number of projects performing HRI through web interfaces [10-13]. However, the majority of the existing approaches on web-based HRI focuses on the creation of remote laboratories for robotic teleoperation, rather than using web technologies for teaching complex tasks to robots.

In this work a novel system is presented that proposes the use of a teaching by demonstration methodology that would significantly reduce the time and required expertise to setup a robotized assembly station. Our system, combining advanced computer vision methods for detecting and tracking manipulated assembly parts, with state-of-the-art semantic analysis of demonstrated assemblies, automatically synthesizes and deploys robot programs for assembly tasks demonstrated by human instructors, using our robotic knowledge integration framework. A web-based Human Robot Interaction (HRI) interface has been designed and developed for assisting human instructors to teach assembly tasks in a straightforward and intuitive manner. The presented work is integrated and demonstrated on an industrial robot setup. The main contributions are:

- A novel approach to automatic generation of robotic assembly programs based on human demonstration;
- a web-based Human Robot Interaction (HRI) interface that can be deployed on portable devices for enabling non-expert users to teach assembly tasks;
- evaluation of the proposed approach on a small-parts assembly use-case featuring teaching of folding assembly operations.

The main focus in this work is integration of all needed components into a framework allowing inexperienced users to teach a robot to perform an assembly task. To the best of our knowledge, this is the first work that integrates all these components for visually teaching a robotic system a new assembly task. The system components are introduced in Section 2, whereas Section 3 presents the experimental setup along with the results on a folding assembly scenario employing two cell phone parts. Our experiments show that the proposed framework is efficient to use, with demonstrated tasks successfully detected, interpreted and deployed to the robot system. Finally, the paper concludes in Section 4.